CONTINUATION APPLICATION FOR UNITED STATES PATENT

FOR

METHOD OF COMPRESSING AN IMAGE

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METHOD OF COMPRESSING AN IMAGE

BACKGROUND

5   The present disclosure is related to compressing images.

As is well-known, image compression techniques are desirable for a variety of purposes. For example, without limitation, images are compressed for storage and/or for transmission across a communications medium. Desirable aspects of image

10   compression techniques include: occupying less storage space; applicability to a wide variety of images; and/or computationally efficient or fast encoding/decoding. Improvements in image compression that include one or all of these aspects continue to be desirable.

15   BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter regarded as the invention is particularly pointed out and distinctly claimed in the concluding portion of the specification. The invention, however, both as to organization and method of operation, together with objects, features, and

20   advantages thereof, may best be understood by reference to the following detailed description when read with the accompanying drawings in which:

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FIG. 1 is a flowchart illustrating an embodiment of a method of compressing an image in accordance with the present invention;

FIG. 2 is a flowchart illustrating an embodiment of a method of decompressing an image that corresponds to the embodiment of FIG. 1.

DETAILED DESCRIPTION

In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the invention. However, it will be understood by those skilled in the art that the present invention may be practiced without these specific details. In other instances, well-known methods, procedures, components and circuits have not been described in detail so as not to obscure the present invention.

As previously discussed, image compression is desirable for a number of applications. Furthermore, it is desirable if such compression techniques occupy less storage space, are applicable to a wide variety of images, and/or have an encoding/decoding process that is computationally efficient or fast.

One technique that is sometimes employed in compression, such as in connection with the wavelet transform, or fractal-based compression/decompression, as two examples, involves a multi-resolution decomposition or multi-level division of the

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image. An embodiment of the present invention, based at least in part on fractal image compression, using an Iterative Function System (IFS), guided by certain probability measures, shall be described in more detail hereinafter. A basic notion of fractal image compression lies in the usage of self-similarity embedded in a given image. Using a set

5 of affine contractive maps, as shall be explained in more detail hereinafter, for example, portions of an image may be reproduced, and by taking a collage of these parts, the entire image may be regenerated. The set of affine contractive maps is referred to in this context as IFS. For a particular embodiment in accordance with the invention, although the invention is not limited in scope in this respect, probabilities are assigned

10 to the maps, which in turn, affect the iteration process, and generate, in this embodiment, a close approximation of the image, employing a manageable amount of computational complexity or computational burden. A way to conceptualize the multi-level division of the image, then, for this particular embodiment, is as a "divide-and-conquer" approach. Therefore, an image may be subdivided and then the subdivisions

15 may be further subdivided in a recursive fashion to determine how to compress the image efficiently.

An embodiment of compressing an image in accordance with the present invention is one such approach. FIG. 1 is a flowchart illustrating this particular

20 embodiment. It is noted that the invention is not limited in scope to this particular embodiment and many variations are possible within the scope of the present invention.

In this particular embodiment, the image, in this embodiment, a gray scale image, I, is divided into quadrants, here designated I_K, where K is 1, 2, 3, and 4. As shall be described in more detail below, the mean (m_K), variance (v_K), and probability (p_K), for each quadrant is calculated, although the invention is not limited in scope in

5 this respect. Other measures, other than the mean (m_K), variance (v_K), and probability (p_K), may alternatively be employed, as described in more detail hereinafter. The variation in gray scale values for the pixels in each quadrant is measured so that each quadrant is classified as a low variation quadrant or a high variation quadrant in terms of its gray scale levels. A low variation quadrant indicates that the image in that

10 particular quadrant is relatively smooth. Therefore, in this particular embodiment, for a low variation quadrant, the gray scale value at each pixel location is replaced with a single gray scale value estimate for the particular quadrant. Of course, in alternative embodiments, multiple estimates of gray scale values may be employed, instead. For the quadrants of the image that are high variation quadrants, these may be estimated

15 using what is referred to in this context as a contractive map of the image along with the probability (p_K), as shall be discussed in more detail. However, if the high variation quadrant may not be accurately estimated using a contractive map of the image, then that particular high variation quadrant is further subdivided and the previous approach is then applied to the subdivisions.

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Although the invention is not limited in scope to a particular approach to measuring the gray scale variation of a quadrant of an image, in this particular embodiment, the gray scale variation is measured using the statistical variance, v_K, of

the gray scale values of a particular quadrant, as indicated above. Then, whether a quadrant qualifies as a low variation quadrant or a high variation quadrant, in this particular embodiment, depends upon the variance of the quadrant measured against a pre-determined threshold value. It is noted that many different approaches to

5   determine a threshold level are possible and the invention is not limited in scope to a particular approach. Likewise, in alternative embodiments, it may be desirable to adjust the threshold depending, at least in part, upon the size of the image or image blocks, or, depending, at least in part, upon the exposure of the particular image, although the invention is also not limited in scope in these respects, as well.

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In one embodiment, a high variation quadrant is where the statistical variance is above or equal to the pre-determined threshold, and a low variation quadrant is otherwise. In another embodiment, a low variation quadrant is where the statistical variance is below or equal to the predetermined threshold, and a high variation

15   quadrant is otherwise.

Likewise, when replacing a low variation quadrant with an estimate of the gray scale level for the particular quadrant, many approaches are possible and the invention is not limited in scope to a single approach. Nonetheless, in this particular

20   embodiment, the statistical mean (m_K) of the gray scale values in the particular quadrant are employed, as previously described. Therefore, if a quadrant is a low variation quadrant, each pixel location gray scale value in that quadrant is replaced by

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the statistically computed mean gray scale value for the quadrant, again, in this particular embodiment.

As indicated above, an attempt is made to estimate particular quadrants using a
5 contractive map of the image along with the probability (p_K). In this particular embodiment, the contractive map is formed by considering non-overlapping windows of size two-by-two contiguous pixels over the entire image and summing the four pixels within the window for the particular pixel location. In this context, this is referred to as a spatial summing filter, here, a two-by-two summing filter. Thus, in this particular
10 embodiment, the size of the contractive map of the image becomes the same as the size of a quadrant of the image.

It is noted, of course, that alternative approaches to forming a contractive map may be employed. For example, a window of size three-by-three or perhaps a window
15 of a shape other than a square shape may be employed. Nonetheless, in addition to forming a contractive map, for the particular quadrant, the probability is calculated for the quadrant. In this embodiment, for a quadrant, the probability of the quadrant is the ratio of the sum of the pixel gray scale values over the quadrant to the sum of the pixel gray scale values over the image. This may be illustrated by the following equation.
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$$p_K = S_K/S, \qquad [1]$$

where S_K is the sum of gray scale values for the pixel locations in quadrant I_K of image I, where K = 1 to 4, and S is the sum of gray scale values for the pixel locations in I; and

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$$\Sigma \, p_K = 1, \qquad [2]$$

where K = 1 to 4.

A particular quadrant is then estimated by multiplying the probability of that quadrant times the contractive map of the image, the multiplication being a scalar multiplication of the contractive map.

Once this is complete for the quadrants of an image, an estimate, I^1, of the image, I, may be formed by combining the estimates for the quadrants. Another image estimate, I^2, is formed by iteratively applying the previous approach, quadrants are estimated using the mean gray scale value and high variation quadrants are estimated using a contractive map of the estimate image, I^1, scaled by the probability of the particular quadrant. If this estimate image, I^2, is equal to the image it was estimated from, I^1, then this recursive estimation process is terminated, and the resulting estimate image, I^1, is divided into quadrants that are compared with corresponding quadrants of the original image. Alternatively, if the estimates are not equal, then the new estimate, I^2, is treated as the image to be estimated and the previously described approach is

recursively repeated until the estimate image, I^{N+1}, equals the image from which it is estimated, I^N, after N such iterations.

Once an estimate, I^{N+1}, equals the image from which it is estimated, I^N, for each

5   quadrant of the estimate image, I^N, low variation quadrants are estimated using mean gray scale values. If the particular quadrant is then "close" to the corresponding quadrant of the original image, I, those quadrants are stored as either the mean gray scale value of the original image, if it was a low variation quadrant, or the probability value for the original image, if it was a high variation quadrant. If all quadrants of the

10   estimate image are close to the original image, compression is complete. However, if some quadrants of the estimate are not close, then those or that quadrant may not be estimated using a mean gray scale value or a contractive map of the image along with the probability (p_K) at this particular stage. Therefore, the previous approach, beginning with subdivision into quadrants, is now applied to that or those quadrants of the original

15   image, and that or those quadrants of the original image are treated as described above. In other words, the quadrant or quadrants are treated as the original image in the previous description, divided into four quadrants, and so forth.

Referring now to Fig. 1 and flowchart 100, at block 110, the image is received or

20   input. It is noted that while the input image comprises an image of gray scale levels, this image may comprise a component of a color image, particularly the intensity component. At block 120, of Fig. 1, the image is divided into four equal quadrants, designated here as I_K, where K varies from one to four, in this particular embodiment.

At block 130, as previously described, for each quadrant I_K, calculate the mean, m_K, the variance, v_K, and the probability, p_K, for each quadrant. These may be computed in the manner previously described. At block 140, compare the variance of each quadrant against a threshold value. If all quadrants have a variance are below the threshold value, at blocks 145 and 155, the image compression is complete by storing the mean gray scale for each respective quadrant. However, alternatively, at block 160, instead, the quadrants are estimated using a contractive map, as previously described.

Blocks 170 and 180 refer to an approach where the estimate of the image is formed from the estimate of the quadrants, the previous calculations are repeated and so forth, until two successive image estimates are equal. Once two successive image estimates are equal, low variation quadrants are estimated using mean gray scale values at block 185. At block 190, the quadrants of the estimate are compared with the quadrants of the original image. At 195, if all of the estimated quadrants are close to the original quadrants, then the entire image is estimated using mean gray scale values and/or probability values, depending on whether a particular quadrant is a low variation quadrant or a high variation quadrant. It is noted, in this context, that any one of a number of different measures may be employed to determine whether the estimate of the quadrant and the corresponding quadrant of the original estimate are "close," such as mean squared error (MSE) and other approaches. If on the other hand, not all the quadrant estimates are close to the corresponding original image quadrants, then for those quadrants that are close, the estimate of the quadrant is employed, whether the mean or the probability for the particular quadrant and, for those quadrants that are not

close, the particular quadrant is treated as an image and is subdivided, at block 120, and so forth. It is noted in this context that for this particular embodiment a quadrant which is estimated and not close to the original image would probably be a high variation quadrant, due to the presence of block 185.

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FIG. 2 is a flowchart illustrating an embodiment 200 of a method of decompressing an image, this embodiment corresponding to the embodiment of FIG. 1. Of course, the decompression process or method will, in general, correspond with the particular compression process or method, and, therefore, the invention is not restricted 10 in scope to the decompression embodiment illustrated.

This embodiment begins with an arbitrary image, J, having the same dimensions as the image to be decompressed, this arbitrary image having at least one zero pixel gray scale value. Therefore, at block 210, this image is read or input and the 15 "codebook" of the compressed image is read or input. At block 220, the mean or average value for the compressed image is read from the codebook. At 230, the average value of the arbitrary image is computed. At 240, the arbitrary image is divided into quadrants. At 250, 260, 270, and 280, if the code for each quadrant from the codebook is a mean value, m_K, then the image is decompressed using these values as 20 indicated in block 270, and decompression is complete.

Otherwise, at blocks 290, 310, and 320, the probabilities from the codebook are employed with a contractive map of the arbitrary image to form a decompression

estimate, J^1. This is then repeated using the next level of the codebook to form decompression estimate, J^2. If these estimates are not equal, this is continued using the codebook until two successive estimates, J^N, and J^{N+1}, are equal, at block 320.

5   If two successive estimates are equal, then, at block 330, the estimate, J^N, is divided into quadrants. If probabilities remain in the codebook, then, at block 340, the corresponding quadrant of J^N is treated as the arbitrary image, J, and the process is recursively applied to this image at block 240. Eventually, once no more codes remain for the probability, at block 350, the resulting image is scaled, and, at block 360, the
10   quadrants in which the mean gray scale level has been stored are reconstructed.

It will, of course, be understood that, although particular embodiments have just been described, the invention is not limited in scope to a particular embodiment or implementation. For example, one embodiment may be in hardware, whereas another
15   embodiment may be in software. Likewise, an embodiment may be in firmware, or any combination of hardware, software, or firmware, for example. Likewise, although the invention is not limited in scope in this respect, one embodiment may comprise an article, such as a storage medium. Such a storage medium, such as, for example, a CD-ROM, or a disk, may have stored thereon instructions, which when executed by a
20   system, such as a host computer or computing system or platform, or an imaging system, may result in a method of compressing or decompressing an image, such as an image of gray scale values, in accordance with the invention, such as, for example, one of the embodiments previously described.

While certain features of the invention have been illustrated and described herein, many modifications, substitutions, changes and equivalents will now occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.